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(54) Electronic camera using incremental image processing

(57) An electronic still camera includes an image sensor for capturing an original image and generating image signals corresponding to the captured original image, an A/D converter for converting the image signals into original digital image data representative of the captured original image, an image processor for incrementally processing the original digital image data to generate processed image data as each increment is processed and completed, and a non-volatile memory for storing the processed image data, wherein the non-volatile memory also temporarily stores the original digital image data until the incremental processing is completed. The incremental processing of the original image data can then be interrupted in order to capture a new image, while the processed image data for the completed increments of the original image is saved in the non-volatile memory.

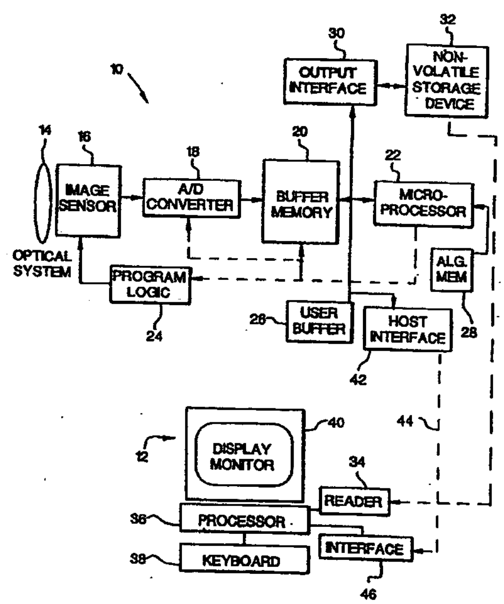

FIG. 1

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ing detailed description of the preferred embodiments and appended claims, and by reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a block diagram of a digital still camera system configured according to the invention to process and store finished files in a removable storage device.

FIG. 2 is a flow diagram describing the operation of the camera shown in Figure 1 in relation to incremental image processing performed according to the invention.

FIG. 3 is a diagram of the image processing steps involved in the generation of finished files.

FIG. 4 is a diagram of the Bayer color filter pattern used in connection with the image sensor in the camera shown in Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Because digital cameras employing electronic sensors and electronic processing and storage are well known, the present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the present invention. Elements not specifically shown or described herein may be selected from those known in the art. Certain aspects of the embodiments to be described may be provided in software. Given the system as described in the following materials, all such software implementation needed to practice the invention is conventional and within the ordinary skill in such arts.

[0011] Figure 1 shows a block diagram of a digital still camera 10 capable of capturing and processing images in accordance with the invention. The images are then delivered to a host computer 12. The digital still camera 10 includes a conventional optical system 14 for directing image light from a subject (not shown) to an image sensor 16. Although not shown as separate elements, the optical system 14 includes conventional lens optics for directing the image light through a diaphragm (which regulates the optical aperture) and a shutter (which regulates exposure time). Alternatively, particularly for sensors that have a light protected readout region, the exposure time can be varied by electrically controlling the readout of the image sensor 16 in a conventional manner. The image sensor 16, which includes a two-dimensional array of photosites corresponding to picture elements of the image, is a conventional charge-coupled device (CCD) using, e.g., either well-known interline transfer, progressive scan, or frame transfer techniques. When the sensor 16 is exposed to image light to capture a particular image, analog image information corresponding to the particular image is generated in respective photosites of the sensor 16. The sensor 16 includes a color filter array pattern, such as the Bayer color filter array pattern shown in Figure 4 and described in U.S. Patent No. 3,971,065, to provide color image data values. Accordingly, the analog image information output by the sensor 16 represents an uninterpolated stream of unique color values, one value for each pixel, corresponding to the color pattern of the color filter array.

[0012] The analog image signals are applied to an A/D converter 18, which generates digital image data from the analog input signals for each picture element. This digital image data is uninterpolated Bayer pattern image data in which each photosite provides a single red, green, or blue value corresponding to its position in the Bayer pattern. The uninterpolated digital image data is applied to a RAM buffer memory 20 having storage capacity for storing one image. A digital microprocessor 22 (for example, a Motorola PowerPC MPC821 processor) generally controls the exposure conditions by generating, via programmable logic 24, the horizontal and vertical clocks needed for driving the sensor 16 and for clocking image information therefrom, and enables the A/D converter 18 in conjunction with the image buffer 20 for each signal relating to a picture element. User interaction with the microprocessor 22 is obtained through a set of user buttons 26, which include a shutter button for initiating an exposure sequence.

[0013] The microprocessor 22 performs certain preliminary processing of the uninterpolated Bayer pattern digital image data, including blemish or defect concealment and white balance, as well as the generation of a reduced resolution thumbnail image and a header for the image file according to a first file format. This preliminary processing is not particularly time intensive and does not significantly impact upon the capture timing of the camera. The preliminarily processed data is then transferred via an output interface 30 to a non-volatile storage device 32 and stored in the first file format. While not necessary for practice of the invention, the storage device 32 is a removable storage device, such as a memory card. This preliminarily processed digital image data in the storage device 32 is described herein as "raw" Bayer pattern image data in which the image data in the image file represents a single red, green, or blue value corresponding to its position in the Bayer pattern.

[0014] Once "raw" digital image data for the captured image has accumulated in the storage device 32, the stored image data is retrieved in incremental stages by the digital processor 22 and processed according to more comprehensive time-intensive image processing algorithms stored in an algorithm memory 28. These image processing algorithms provide, e.g., color filter array (CFA) interpolation, color correction, tone scale correction, edge enhancement, and compression. The processed image data is then transferred via the output interface 30 to the non-volatile storage device 32 in a

image data files.

[0020] Because of the minimal processing required, the time between starting the sensor readout and completely storing the Bayer pattern TIFF file in the storage device 32 is short (for example, 2 seconds). Once the "raw" image is stored in the storage device 32, the camera is ready to take another picture, as soon as the user again presses the shutter button in the user button section 26. However, if the user does not immediately press the shutter button, the microprocessor 22 in the camera begins to perform image processing of the stored "raw" Bayer pattern TIFF image, in order to create a "finished" JPEG interchange format image file format as described in ISO/IEC 10918-1:1994. The microprocessor 22 checks to see how many unprocessed TIFF images exist (step 112), and begins to process the first unprocessed segment of the oldest TIFF image (step 114). A segment may, for example, contain the data values for a 16 row by 64 column area of the image.

[0021] The oldest image is first checked to determine if it is partially processed (step 116). If the oldest image has no processed segments, the microprocessor 22 begins to create a new JPEG file (step 118) by writing the JPEG header information, which includes the start of image and start of image JPEG segments, as well as an application segment, such as the Exif application segment described in "Digital Still Camera Image File Format Standard"(Exif), version 1.1, Japan Electronic Industry Development Association (JEIDA), May, 1997. This Exif application marker includes the TIFF thumbnail data and other TIFF tags, for example the DateTime tag and the Fnumber tag.

[0022] The microprocessor 22 then processes each image segment (step 122) using the processing steps shown in Fig 3. Exemplary steps include CFA interpolation 200, color correction 202, tone scale correction 204, edge enhancement 206, and JPEG compression 208. Typical CFA interpolation techniques for a Bayer pattern are described in U.S. Patent Nos. 5,506,619 and 5,629,734. Examples of typical color correction, tone scale correction and edge enhancement are found in <u>Digital Image Processing</u>, 2nd ed., by William Pratt, Wiley, 1991 and <u>Fundamentals of Digital Image Processing</u>, by A.K. Jain, Prentice-Hall, 1989. The color image data may also be converted into JPEG standard color space (YCC CCIR 709 space) and downsampled to improve the compression ratio for chroma. A typical JPEG compression algorithm is the Discrete Cosine Transform (DCT). The processor begins by reading from the TIFF file the data needed to process the next segment (step 120). This data may be slightly larger than the 16 x 64 pixel segment, since the values of "neighbor" pixels are needed to properly perform the color filter array and edge enhancement processing. After the segment processing is completed, the microprocessor 22 checks to see if this was the last segment of the image (step 124). If there are more segments, then data needed for the next segment is read from the TIFF file (step 120) and that segment is processed (step 122).

[0023] The JPEG interchange format (JIF) file is complete after the last segment of the image has been processed. This process may take approximately 20 seconds per image, much longer than the time to capture and store the "raw" TIFF file. After all image segments are fully processed, the TIFF file corresponding to the unprocessed image can be deleted (step 126).

[0024] The purpose of saving each incremental step (i.e. saving the result of processing each segment) is to maintain earlier processing in case the user attempts to take another picture before the processing shown in Fig. 3 is completed for the entire image (i.e. within 20 seconds of taking the last image). During any of the processing steps shown within the right-hand box 128 in Fig. 2, if the user wants to capture a new image, the shutter button in the user button section 26 is pressed, an interrupt section 130 is enabled and processing is returned to the capture sequence (steps 102-110). In particular, the processing of the current segment (step 122) is halted (or alternately, aborted) and the user is allowed to capture a new image (step 102), which is immediately processed (according to steps 104-108) and stored on the removable storage device 32 (step 110). Following the image capture(s) and storage, the previously halted incremental image processing step 122 is resumed at the point of interruption (or the aborted segment is reprocessed). With this approach, the portion of the image processing that is lost is minimized to (at worst) the incremental step which was aborted and not to any previous incremental steps. This incremental image processing continues until the image is finished.

[0025] While this example showed the incremental image processing performing the full set of algorithms on many (24 x 64 = 1536) image segments, it is also possible to completely process the full image sequentially using each algorithm shown in Fig. 3, and storing the intermediate results in the non-volatile memory, or by sequentially storing the output of each processing step for each segment in the non-volatile memory 32. In these two cases, after finishing a subsequent incremental step, the microprocessor 22 would erase the results of the previous step.

[0026] In summary, the invention is a camera architecture that uses the camera non-volatile transfer memory (such as a PCMCIA type III hard drive) to store image files as they are incrementally processed, and interrupts this processing whenever the user decides to take a new image. In effect, the camera processes images only during the idle times, i.e. times the camera isn't being used to capture an image. When the user wants to capture a new image, the camera "suspends" the image processing operations on the previously captured "older" images, allows the user to capture "new" images, then resumes image processing of the older images, followed by the newer image. This allows the time between captured images to be minimized, without

each processed segment in the removable memory as the processing for each segment is completed. Or the method may incrementally perform a series of processing steps and store the results of each step in the removable memory as the processing for each step is completed, or incrementally processing the captured image in segments and further incrementally performing a series of processing steps on each segment and storing the results of each step for each processed segment in the removable memory as the processing for each step within a segment is completed.

[0031] The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

PARTS LIST

[0032]

10	digital still camera
12	host computer
14	optical system
16	image sensor
18	A/D converter
20	RAM buffer memory
22	digital microprocessor
24	programmable logic
26	user button section
28	algorithm memory
30	interface
32	removable, non-volatile storage device
34	card reader
36	processor
38	keyboard
40	monitor
42	host interface
44	cable
46	interface

Claims

1. An electronic still camera for capturing an original image and performing image processing on the original image, said camera comprising:

   an image sensor for capturing the original image and generating image signals corresponding to the captured original image;
   an A/D converter for converting the image signals into original digital image data representative of the captured original image;
   an image processor for processing the original digital image data to generate processed image data; and
   a non-volatile memory for storing the processed image data, wherein the non-volatile memory also temporarily stores the original digital image data at least until the image processor completes image processing of the original digital image data.

2. A camera as claimed in claim 1 wherein the original image data is stored in a first file format and the processed image data is stored in a second file format.

3. A camera as claimed in claim 2 wherein the original image data is stored in a TIFF file format and the processed image data is stored in a JPEG file format.

4. A camera as claimed in claim 1 wherein the image processor can be interrupted in order to capture another image.

5. A camera as claimed in claim 1 wherein the image processor implements incremental image processing such that the results of each increment are stored as each increment of processing is completed.

6. A camera as claimed in claim 5 wherein the incremental image processing processes the captured image in segments and stores the data for each processed segment in the non-volatile memory as the processing for each segment is completed.

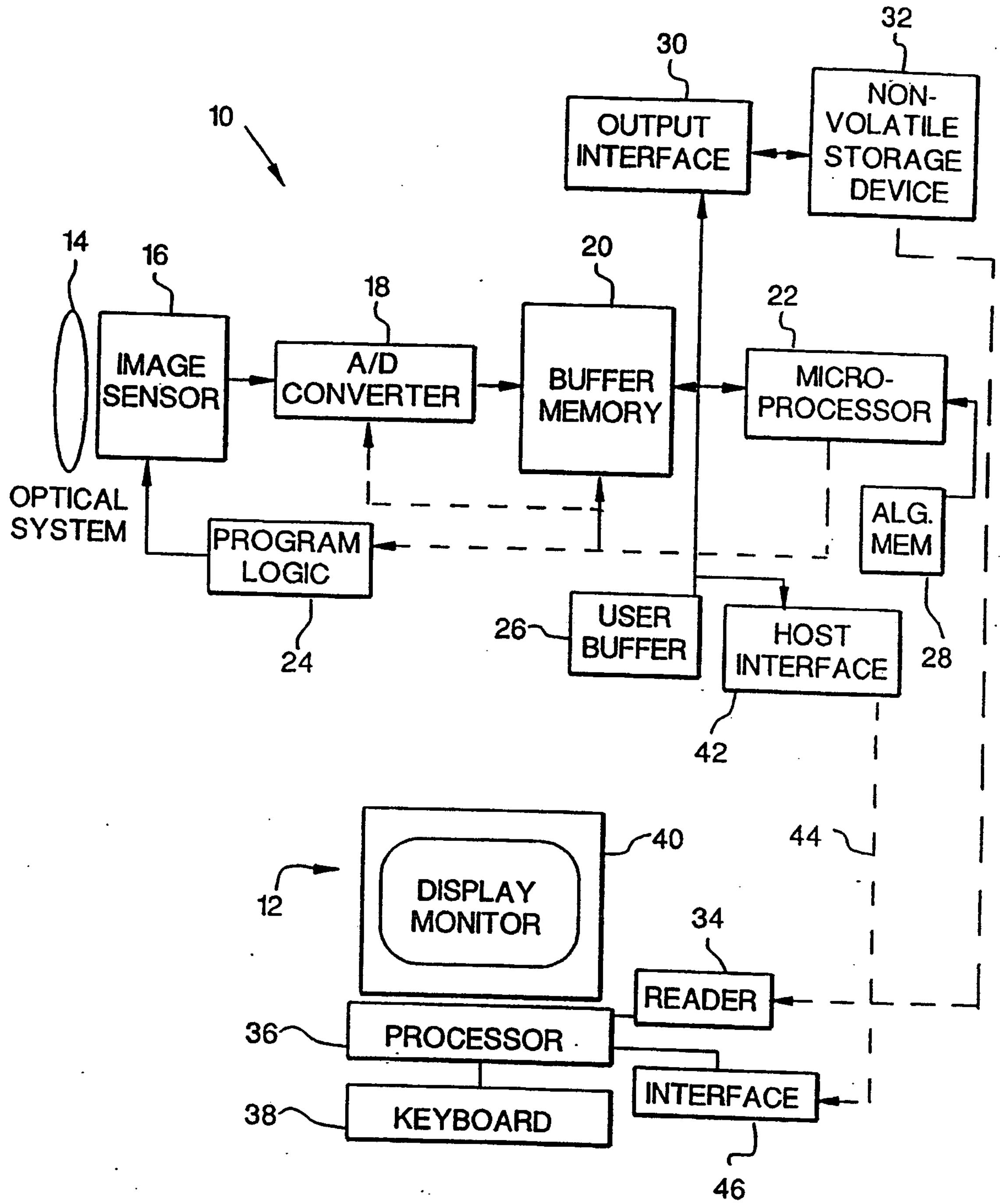
7. A camera as claimed in claim 6 wherein the processed segments are stored in a JPEG interchange format bitstream separated by restart markers.

8. A camera as claimed in claim 5 wherein the incremental image processing performs a series of processing steps and stores the results of each step in the non-volatile memory as the processing for each step is completed.

9. A camera as claimed in claim 6 wherein the non-volatile memory is also removable.

10. A method utilizing an electronic still camera for capturing an original image and performing image processing on the original image, said method comprising the steps of:

    generating a capture signal in order to initiate an image capture of the original image;
    capturing the original image and generating image signals corresponding to the captured original image;
    converting the image signals into original digital image data representative of the captured original image;
    incrementally processing the original digital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OPTICAL SYSTEM
IMAGE SENSOR
A/D CONVERTER
BUFFER MEMORY
MICRO-PROCESSOR
PROGRAM LOGIC
OUTPUT INTERFACE
NON-VOLATILE STORAGE DEVICE
ALG. MEM
USER BUFFER
HOST INTERFACE
DISPLAY MONITOR
READER
PROCESSOR
KEYBOARD
INTERFACE

FIG. 1

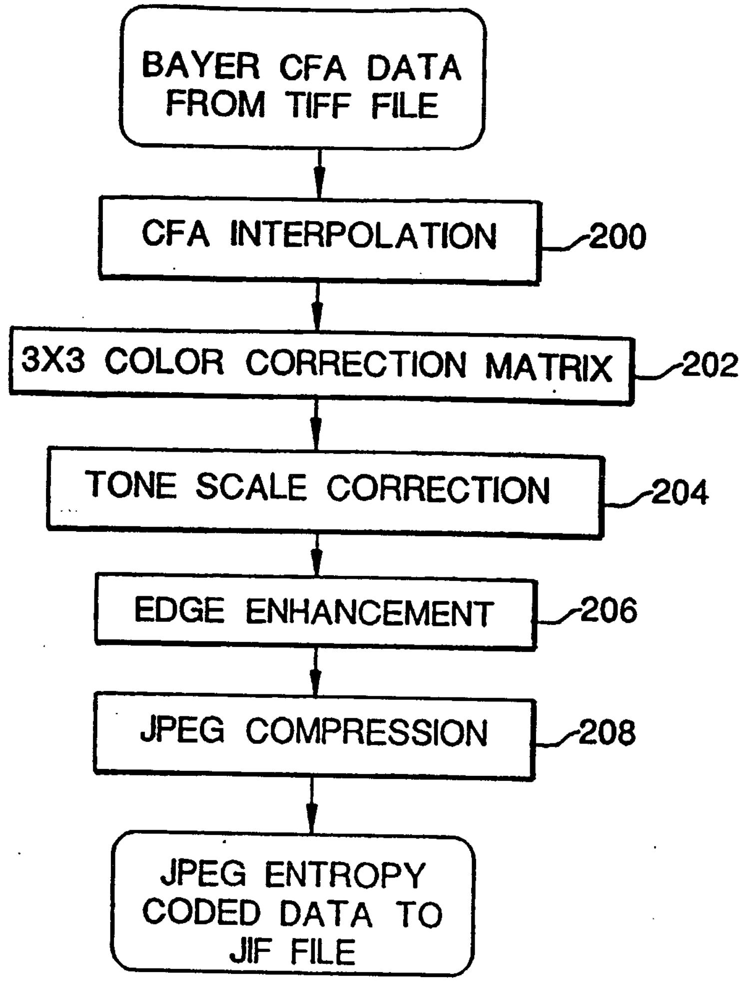

FIG. 3

G	R	G	R	G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R	G	R	G	R

FIG. 4

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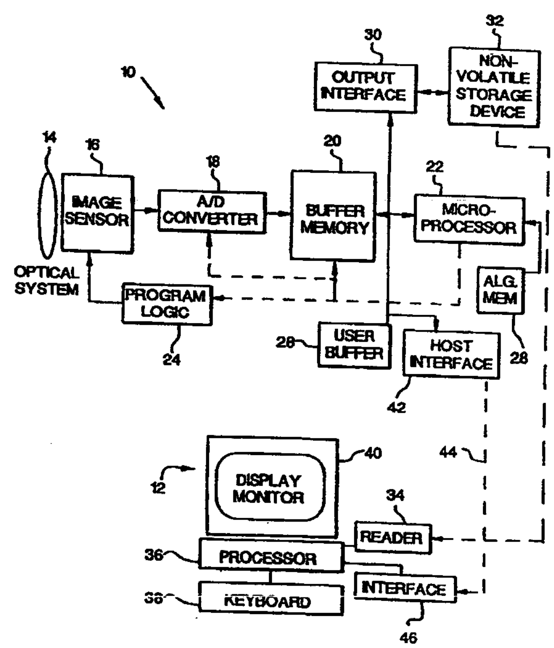

FIG. 1

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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